Spurred Anoda: A Potential Weed in Southern Crops

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Spurred Anoda: A Potential Weed in Southern Crops

By J. M. Chandler[1] and L. R. Oliver[2]

ABSTRACT

Within 10 years, spurred anoda [*Anoda cristata* (L.) Schlecht.] has made an economic impact on cotton production in the Midsouth region of the United States because of its ability to germinate, grow, and produce viable seeds throughout the growing season, its ability to obtain enough leaf area and size to become competitive, and its resistance to several widely used herbicides in weed-control programs. In research at Fayetteville, Ark., and Stoneville, Miss., spurred anoda, when confined to the cultivated band, was competitive with cotton but not with soybeans. Full-season competition from 4 to 80 spurred anoda plants per 12 meters of row reduced seed-cotton yields 12 to 69 percent, respectively. Competition between spurred anoda plants greatly influences its yield-reducing potential in cotton. Spurred anoda requires 6 weeks of growth and development before it exerts a competitive influence on cotton. Control of densities as low as 4 spurred anoda plants per 12 meters of row emerging within the first 3 weeks after cotton emergence are economically feasible. An excellent control system in cotton was norflurazon applied preemergence, followed by methazole plus MSMA post-directed at 3- to 4-inch cotton and repeated at 6- to 8-inch cotton. Crop rotation from cotton to soybeans would be a very effective means of controlling spurred anoda since soybeans are stronger competitors, and effective herbicides for spurred anoda control in soybeans are available. Corn or grain sorghum would also be excellent rotation crops since several widely used herbicides in these crops provide excellent control of spurred anoda. Index terms: corn, cotton, methazole, MSMA, norflurazon, spurred anoda, sorghum (grain), soybeans, weed control.

INTRODUCTION

Spurred anoda [*Anoda cristata* (L.) Schlecht.] has become, in a relatively short period, a serious pest in cotton (*Gossypium hirsutum* L.) and a potentially serious pest in soybeans [*Glycine max* (L.) Merr.] and other agronomic crops in the humid Southern United States. Spurred anoda is the most common of the 10 *Anoda* species that have been identified in the Western Hemisphere (Gleason 1952). It is a tropical weed native to South America, Central America, and the Southwestern United States and has been reported frequently from Arizona to North Carolina and from Iowa to Louisiana. The weed adapts equally well to cultivated fields, gravel banks, and open woods (Gleason 1952, Correll and Johnson 1970).

In cultivated fields, spurred anoda was first observed in Arizona and New Mexico during the early 1950's and in Texas, Arkansas, and Mississippi in the late 1960's (Chandler 1977a). In the early 1970's it was classified as one of the 10 most troublesome

[1]Research agronomist, Southern Weed Science Laboratory, Science and Education Administration, U.S. Department of Agriculture, P.O. Box 225, Stoneville, Miss. 38776.

[2]Assistant professor, Department of Agronomy, University of Arkansas, Fayetteville, Ark. 72701.

weeds in cotton in Arkansas and Mississippi (Buchanan 1971, 1974a). By 1974 it had infested 700,000 hectares (1.9 million acres) of cotton in the Southern United States (Buchanan 1974b). Figure 1 shows the areas of spurred anoda infestation in cotton in 1971 and the areas of additional infestation in 1976. The most rapid spread occurred in Arkansas, central and northern Mississippi, northwestern Alabama, and southwestern Tennessee, but an increase was also noted in northeastern North Carolina and southeastern Virginia (Chandler 1977a). The increased occurrence has been due to widespread herbicidal control of annual weeds that previously interfered with spurred anoda growth. Spurred anoda itself has not been controlled by the herbicides used (Baker and Ivy 1973, Abernathy et al. 1976, Chandler 1977a).

Because of the aggressive growth habits of spurred anoda and the possibility that it could develop into a serious weed problem in cotton and soybean fields of the Mississippi Delta, research was initiated in 1972 at the Southern Weed Science Laboratory, Stoneville, Miss., and at the University of Arkansas, Fayetteville, to investigate its biology, competitiveness with cotton and soybeans, control, and potential economic impact. Some of the information has already been published and is summarized herein along with new information on these topics.

BIOLOGY

Identification

Spurred anoda can be a serious problem in cottonfields because the producer may not notice an infested area until late in the growing season. The lack of recognition results from the similarity of cotton and spurred anoda, both of which belong to the same botanical family, the Malvaceae. Early identification is important because, as will be shown later, successful control is economically feasible only in the first few weeks after cotton emergence.

Spurred anoda is an annual that germinates in early spring with cotton and continues to emerge throughout the growing season. The cotyledonary leaves are much smaller than those of cotton, but seedlings may go unnoticed in the cotton drill (fig. 2). In a young spurred anoda plant, the simple, pubescent, dark-green leaves, with either irregularly toothed or entire margins, resemble cotton leaves in size, shape, and color (fig. 3). As the plant matures, the leaves become more triangular (somewhat arrow shaped). A purplish spot not found on cotton leaves occurs on the center vein of the leaf, starting near the stem on the first true leaves and extending farther on older leaves (fig. 4). Throughout the growing season spurred anoda and cotton grow at similar rates, and at a distance they

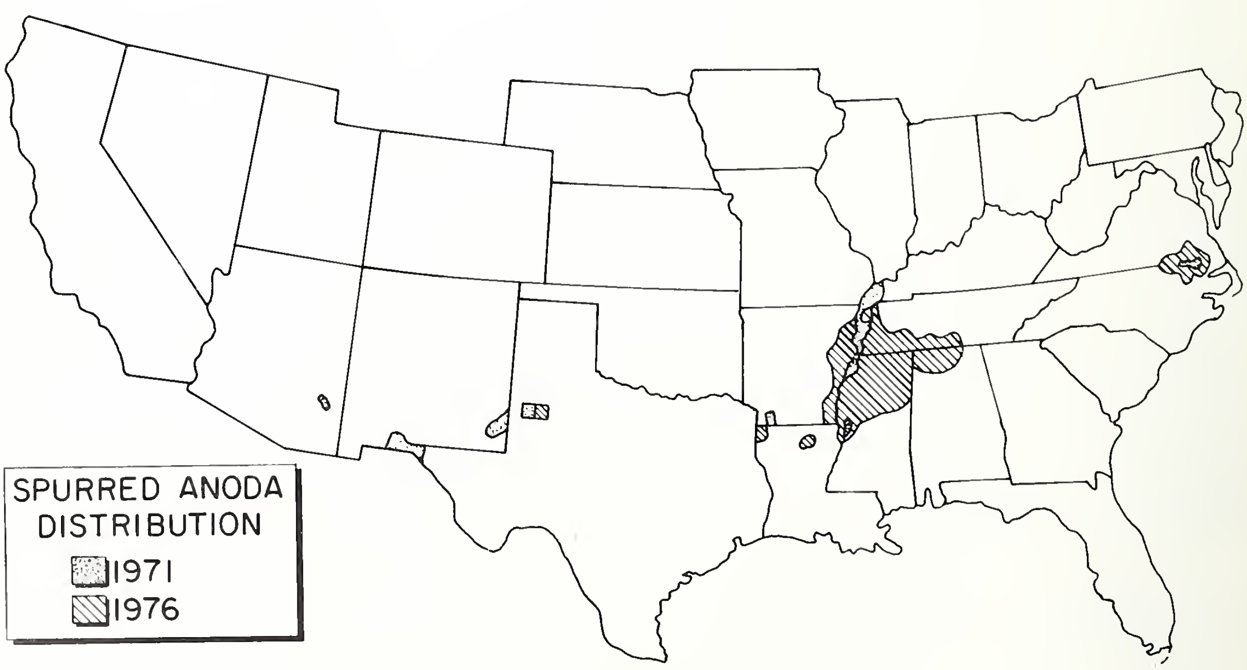

FIGURE 1.—Distribution of spurred anoda in cotton in the United States, 1971 and 1976.

cannot be distinguished. At maturity, spurred anoda is 1 to 2 meters tall, the leaves are 5 to 10 centimeters long, and the branches, which originate from the base and can root at the nodes, are 1 to 2 meters long (fig. 5). This lateral branching severely hampers the operaton of mechanical pickers at harvest.

Spurred anoda blooms from July through October and fruits from August through November. Flowers with five purple or bluish-violet petals are solitary on a slender stalk arising at the base of the leafstalk (fig. 6). The mature calyx is saucer shaped, about 3 centimeters wide, and often purplish red (fig. 7). The compound pistil has 15 to 20 conspicuously beaked carpels that disperse achene fruit when the capsule is broken. The black seeds are naked to slightly pubescent.

Germination and Seedling Emergence

Temperature conditions for spurred anoda germination and emergence are very similar to those for cotton. Solano et al. (1976a) found that the germination of spurred anoda seed is unaffected by light but that it increases as temperature increases. In their investigations germinaton of scarified seed rose from 50 to 85 percent when temperature was increased from 18° to 30° C. Alternation of night temperatures aided germination, indicating that alternating temperatures play an important role in breaking dormancy under field conditions.

Seedling emergence is also temperature dependent. Smith and Cooley (1973) found that spurred anoda emerged within 5 days when soil temperature was maintained at 24° C. Emergence occurred within 12 days at 30° C, but 24 days were required at 18° C. Several studies (Smith and Cooley 1973, Chandler and Dale 1974, Solano et al. 1974) have shown that seedling emergence of both scarified and nonscarified spurred anoda seed is greatest from a soil depth of 1.2 centimeters, but ample emergence occurs from depths down to 7.5 centimeters. Seeds germinate at depths of 12 to 15 centimeters, but the seedlings do not emerge.

Vegetative Growth

We studied the growth of spurred anoda under noncompetitive conditions (plants spaced 3 meters apart) at Stoneville, Miss. Data were collected every 2 weeks, following emergence on May 29, 1973, for 16 weeks. Height followed a sigmoid growth curve (fig. 8A). Growth (as indicated by height) was not significantly different from week to week for the first 4 weeks after emergence. A maximum average height of 175 centimeters was reached after 14 weeks. As measured by dry-plant weight, growth was very slow for the first 6 weeks but very rapid from 6 to 14 weeks after emergence (fig. 8B). Average dry-plant weight by 16 weeks was 900 grams. Both the number of leaves per plant (fig. 8C) and the leaf area per plant (fig. 8D) remained low for the first 6 weeks. Between 6 and 8 weeks a large number of leaves emerged and expanded, as indicated by the rapid increase in leaf area. Between 8 and 10 weeks numerous lateral branches developed from the base of the plant. [Solano et al. (1976b) have stated that branching occurs between the 5th and 9th week.] As a result of branching, a large number of leaves appeared between 12 and 14 weeks, and leaf area steadily increased. After 16 weeks the number of leaves and leaf area per plant were 4,100 and 200 square decimeters, respectively.

Seed Production and Longevity

In our Stoneville study, mature seed capsules and seeds were observed 13 weeks after emergence (May 29, 1973). Peak capsule and seed production occurred 17 weeks after emergence (fig. 9). One plant produced 1,920 capsules with 19,000 seeds. In North Carolina, spurred anoda grown at densities of 10 plants per meter of row produced an average of 159 seed capsules per plant, with an average of 14 seeds per capsule (Solano et al. 1976b). The differences in seeds per plant between the Mississippi and North Carolina studies were due to intraspecific competition, or plant density.

Since spurred anoda germinates and emerges in the field until October and since the mature seed develops a hard impermeable coat, it is important to know the number of mature seeds produced by plants emerging during the late summer and early fall prior to frost. At Stoneville, plants emerging from seeds planted July 27 produced 828 and 1,156 mature seeds by October 11 and 24, respectively (table 1). When planting was delayed 2 weeks, only 376 seeds per plant were produced by November 5. Spurred anoda planted August 24 and September 14 produced only 39 and 12 seeds per plant, respectively, by November 5. Even so, the small quantities of seed produced by November 5 from August 10 and later plantings were adequate to produce substantial plant populations the following year.

(*Continued on page 7.*)

FIGURE 2.—Spurred anoda seedling with one true leaf. The cotyledonary leaves of cotton are larger.

FIGURE 3.—Young spurred anoda plant, about 6 weeks old. At this stage spurred anoda looks most like cotton. This plant is about 50 centimeters tall.

FIGURE 4.—Mature spurred anoda leaf. Note the purple vein, a characteristic not found in cotton.

FIGURE 5.—Mature spurred anoda plant. This plant is at least 12 weeks old and about 1.5 meters tall.

FIGURE 6.—Typical spurred anoda flower, about 4 centimeters in diameter.

FIGURE 7.—Star-shaped seed capsule of spurred anoda. Under certain climatic conditions, the capsule will be purplish red.

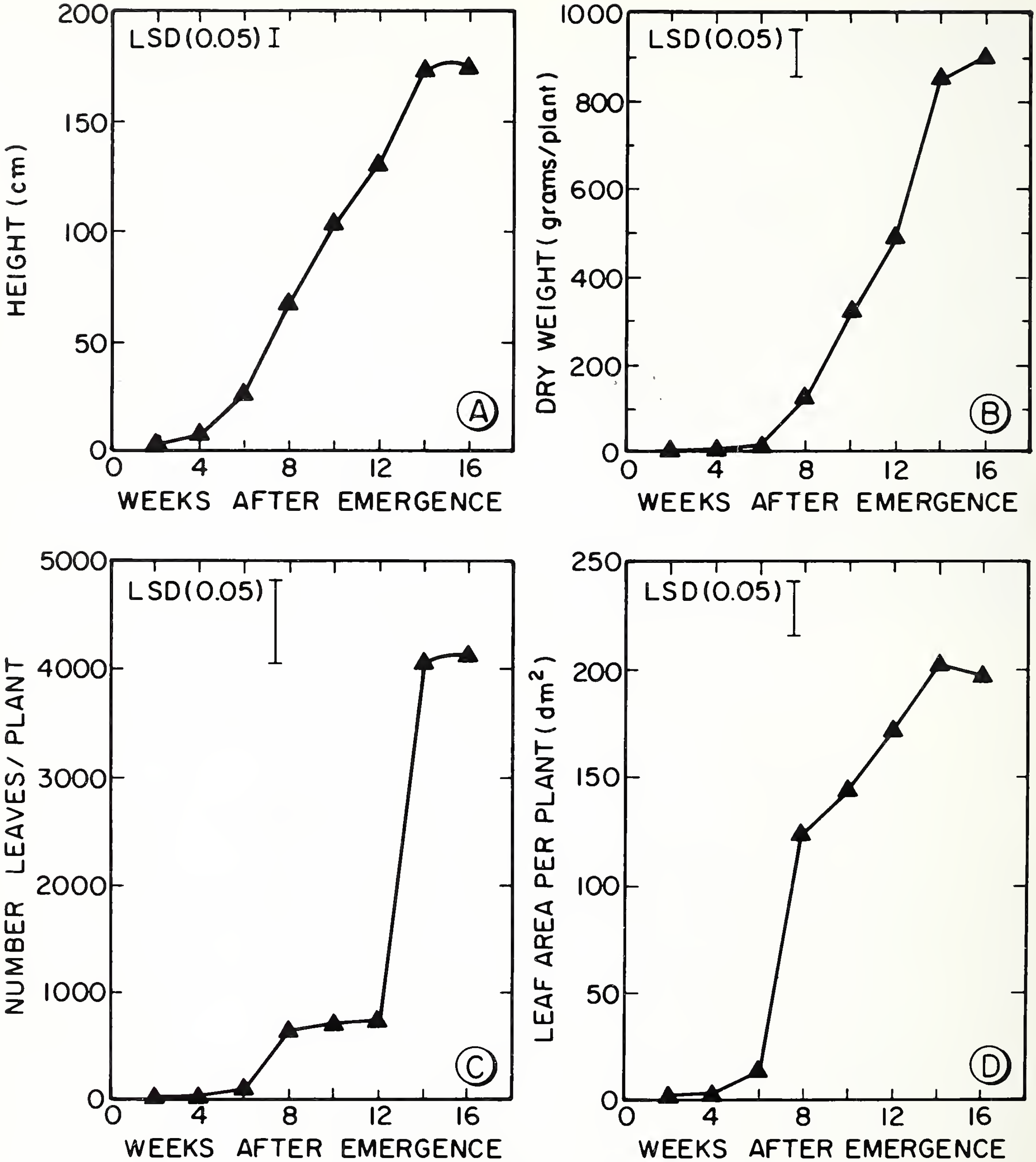

FIGURE 8.—Vegetative development and growth of spurred anoda spaced 3 meters apart during the growing season, Stoneville, Miss., 1973. A, Height. B, Dry weight. C, Number of leaves per plant. D, Leaf area per plant. LSD=Least significant difference.

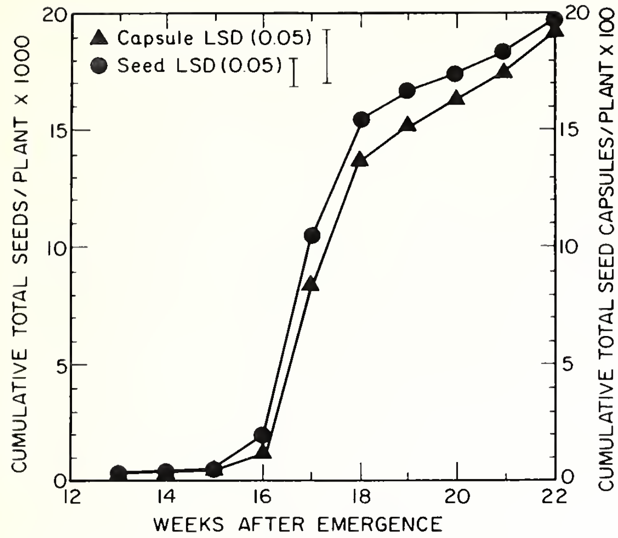

FIGURE 9.—Full-season production of spurred anoda seed capsules and seeds, Stoneville, Miss., 1973. LSD=Least significant difference.

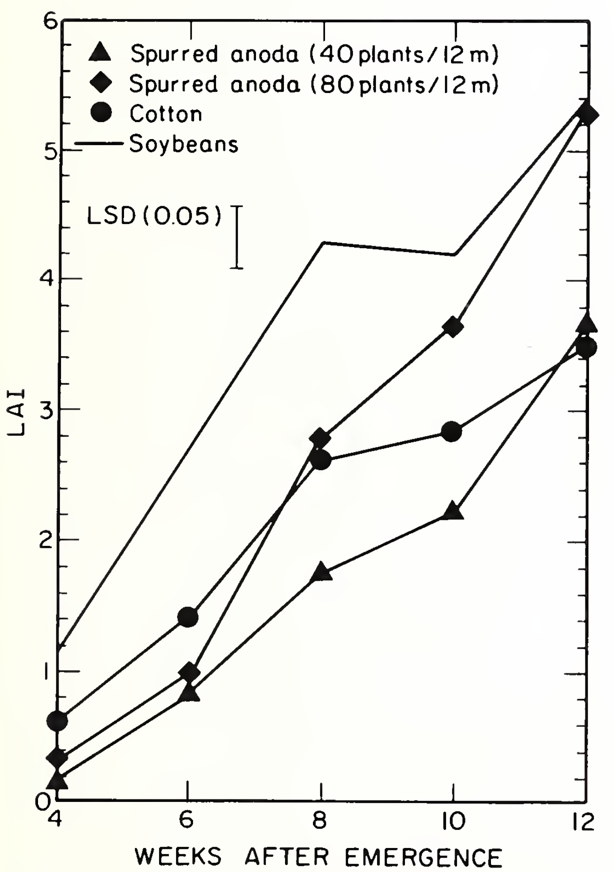

FIGURE 10.—LAI's of soybeans, cotton, and spurred anoda grown separately, Fayetteville, Ark., 1973–74. LSD=Least significant difference.

Table 1.—Production of mature spurred anoda seeds in late plantings at Stoneville, Miss., 1973

[Cumulative average number of seeds per plant, by planting date]

Planting date (1973)	Date of seed collection[1]		
	October 11	October 24	November 5
July 27	828a	1,156a	1,162a
August 10	85b	361b	376b
August 24	0b	25c	39c
September 14	0b	0c	12c
September 28	0b	0c	0c

[1]Means in the same column not followed by a common letter differ significantly from one another at the 5-percent level by Duncan's multiple-range test.

The seeds of many Malvaceae are impermeable to water even when they are embedded in moist soil (King 1966). In a laboratory study by Solano et al. (1974), the dormancy of spurred anoda seed was not broken 60 days after harvest by stratification, by presoaking in tapwater, or by treatment with thiourea, potassium nitrate, or kinetin; of the methods tried, only mechanical scarification and scarification with concentrated sulfuric acid were successful. After treatment with sulfuric acid, 76 percent of seeds buried in the field (North Carolina) up to 20 months germinated, whereas the germination of untreated seeds ranged from 0.5 to 3.0 percent. Depth of burial, ranging from 8 to 38 centimeters, had little effect on seed longevity, but the impermeable seedcoat did affect length of seed dormancy. A study conducted at Stoneville, Miss., by Egley and Chandler (1978) showed that spurred anoda seed buried and recovered 6, 18, or 30 months later had germination levels of 0, 6, and 8 percent, respectively. After the seedcoats were punctured, the level of seed germination increased to 91, 84, and 71 percent, respectively.

These results indicate that seedcoat impermeability is a major factor inhibiting germination of spurred anoda seed. Under field conditions, seeds germinate only after scarification by physiochemical disruptions, mechanical means, or softening and wearing down of the seed coat over long periods of time.

COMPETITION WITH COTTON AND SOYBEANS

The competitiveness of spurred anoda in cotton and soybeans has been investigated at Fayetteville, Ark., and at Stoneville, Miss. (Lambert and Oliver

1975, Lambert 1977, Chandler 1977b). The results of these studies are summarized in the following sections.

Comparative Growth of Spurred Anoda, Cotton, and Soybeans

When soybeans, cotton, and spurred anoda were grown separately, each species had a similar increase in LAI (leaf area index, or leaf area per unit area of land) across time. In figure 10, note that the LAI's of spurred anoda at a density of 40 plants per 12 meters of row and of cotton were similar throughout the growing season. The LAI of spurred anoda at 80 plants per 12 meters was equal to that of cotton at 7 weeks, and spurred anoda maintained a greater LAI for the remainder of the growing season. The high-density planting of spurred anoda did not reach an LAI equivalent to that of soybeans until the 12th week because of the rapid increase in soybean LAI between the 4th and 8th week. These findings indicate that spurred anoda does not have the potential to become competitive with soybeans but that it may be more aggressive than cotton after 6 or 7 weeks.

Plant growth rate (dry-plant weight per unit of land area per unit of time) at specific time intervals also indicates the potential competitiveness of these three species. The growth characteristics of spurred anoda in greenhouse and field studies indicate that cotton has an advantage over spurred anoda during early growth and development (Potter 1976). In North Carolina, dry weight of spurred anoda did not equal that of cotton until 45 days after planting (Solano et al. 1976b). At Fayetteville, Ark., spurred anoda growth rates 6 weeks after emergence were 4.9 grams per square meter per day at a density of 40 plants per 12 meters of row (fig. 11) and 7.0 grams per square meter per day at a density of 80 plants per 12 meters (fig. 12), as compared to a growth rate of 5.0 grams per square meter per day for cotton (fig. 13). Ten weeks after

Table 2.—Fresh weight of mature spurred anoda plants at five densities, Stoneville, Miss., 1973–74

Density (plants/12 m)	Weight[1] (g/plant)	Density (plants/12 m)	Weight[1] (g/plant)
4	2,772a	32	1,119c
8	2,010b	64	254d
16	1,302c		

[1]Means not followed by a common letter differ significantly from one another at the 5-percent level by Duncan's multiple-range test.

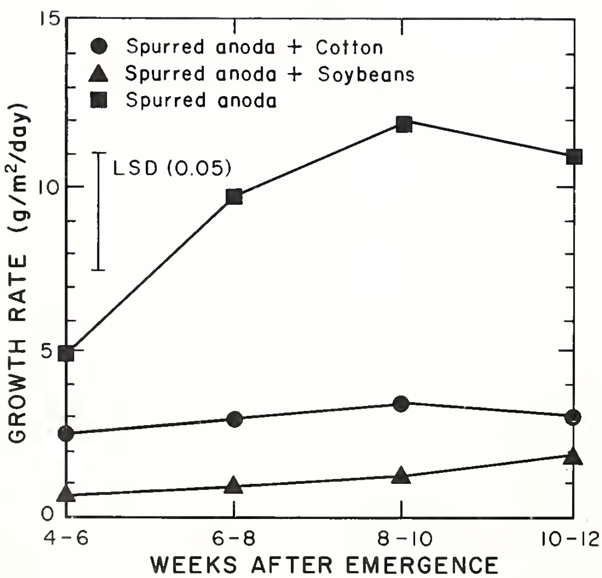

Figure 11.—Effect of cotton or soybean competition on the growth rate of spurred anoda at 40 plants per 12 meters of row, Fayetteville, Ark., 1973–74. LSD=Least significant difference.

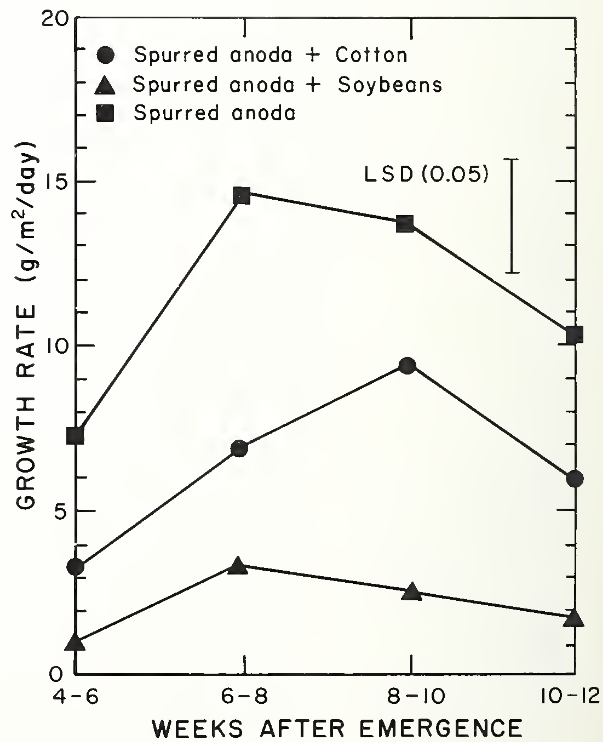

Figure 12.—Effect of cotton or soybean competition on the growth rate of spurred anoda at 80 plants per 12 meters of row, Fayetteville, Ark., 1973–74. LSD=Least significant difference.

emergence spurred anoda increased in dry weight at rates of 11.5 and 14.0 grams per square meter per day at the 40- and 80-plant densities, respectively, while cotton was growing at a rate of 8.5 grams per square meter per day. The rapid increase in spurred anoda growth at 10 weeks demonstrates its potential competitiveness in cotton. Spurred anoda is influenced by competition with other spurred anoda plants (table 2). Densities greater than 32 spurred anoda per 12 meters caused a drastic reduction in plant size, with significant reduction occurring at 8 plants per 12 meters.

Effect of Cotton and Soybean Competition on Spurred Anoda Growth

When spurred anoda was grown with soybeans or cotton, its LAI was reduced significantly, 88 and 73 percent, respectively, at 80 plants per meter of row (fig. 14). At this plant density, the LAI was 1.0 at 7 and 10 weeks when competing with cotton and soybeans, respectively. Oliver et al. (1976) and Barrentine and Oliver (1977) have shown that, at an LAI of 1.0, entireleaf morningglory [*Ipomoea hederacea* (L.) Jacq. var. *integriuscula* Gray], previously referred to as tall morningglory [*Ipomoea purpurea* (L.) Roth], and common cocklebur (*Xanthium pensylvanicum* Wallr.) become competitive with soybeans. Thus, it appears that spurred anoda has obtained enough leaf area and size to become competitive at 7 weeks in cotton and at 10 weeks in soybeans.

Competition with soybeans or cotton reduced the growth rate of spurred anoda and the total growth (dry weight per plant). The greatest reduction in growth rate occurred from soybean competition, with an 85-percent reduction at 40 plants per 12 meters of row (fig. 11) and an 80-percent reduction at 80 plants per 12 meters (fig. 12) 12 weeks after emergence. In cotton, the growth rate was reduced by 65 and 40 percent at 40 and 80 plants per 12 meters of row, respectively. These values indicate

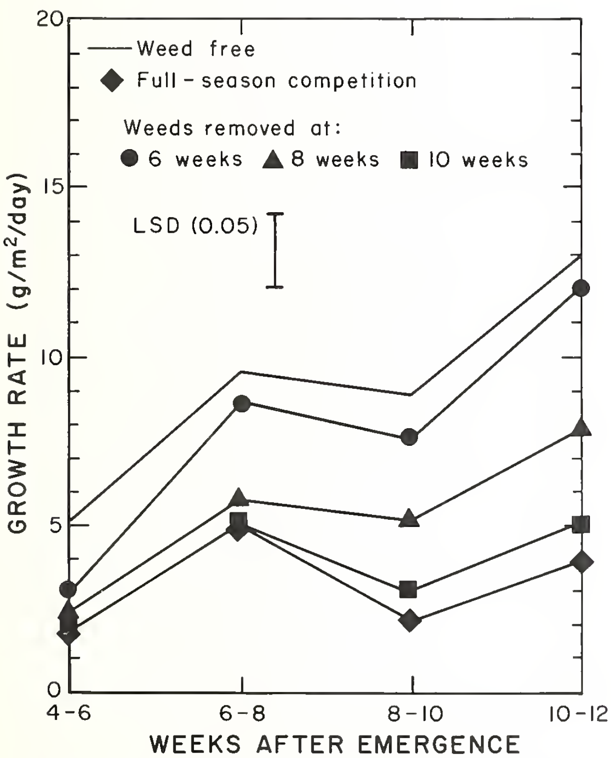

FIGURE 13.—Effect of spurred anoda competition (40 plants per 12 meters of row) on the growth rate of cotton, Fayetteville, Ark., 1973–74. LSD = Least significant difference.

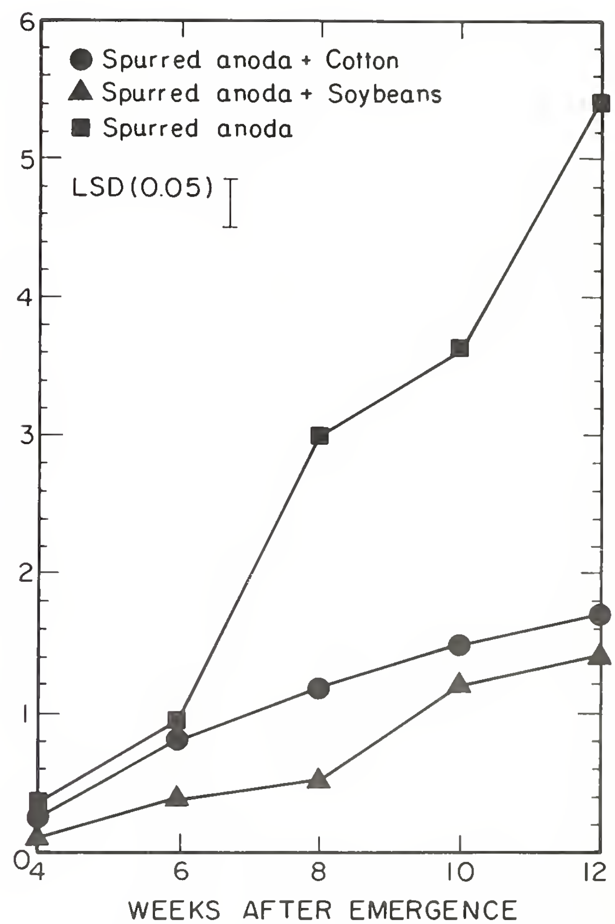

FIGURE 14.—Effect of cotton or soybean competition on the LAI of spurred anoda at 80 plants per 12 meters of row, Fayetteville, Ark., 1973–74. LSD = Least significant difference.

that soybeans exert more competitive pressure on spurred anoda than cotton.

The dry weight of spurred anoda plants was reduced by 45 percent when emergence was delayed for 2 weeks after cotton emergence at densities of 4 plants per 12 meters of row (table 3). At densities from 8 to 64 plants per 12 meters of row, there was not a reduction in plant dry weight produced at similar levels of competition from plants emerging 2 weeks after cotton as compared to those emerging with cotton. Spurred anoda plants that emerged 4 weeks after cotton emergence were unable to effectively compete with cotton.

Effect of Spurred Anoda Competition on Cotton and Soybean Growth and Yield

Cotton growth varied as spurred anoda density and the duration of competition increased. Removal of spurred anoda (40 plants per 12 meters of row) 6 weeks after emergence allowed cotton to maintain a growth rate equivalent to that of cotton growing alone; however, competition for periods longer than 6 weeks caused significant reductions in the cotton growth rate (fig. 13). At 8 weeks, cotton without competition was increasing in dry weight at a rate of 9.8 grams per square meter per day, as compared to 4.0 grams per square meter per day when competing with spurred anoda. Full-season competition reduced cotton growth rate 60 percent.

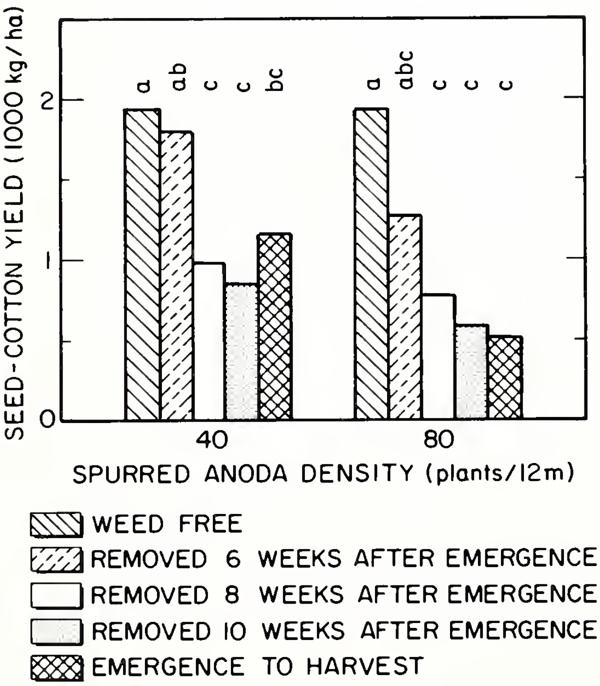

Figure 15.—Seed-cotton yields as influenced by spurred anoda competition at five durations and two densities, Fayetteville, Ark., 1974. Data bars not followed by a common letter differ significantly from one another at the 5-percent level by Duncan's multiple-range test.

Cotton-yield reductions increased as spurred anoda density and the duration of competition increased (figs. 15 and 16). At Fayetteville, Ark., significant yield reduction did not occur if spurred anoda at 40 plants per 12 meters was removed during the first 8 weeks (fig. 15); however, yields were reduced after 6 weeks at a spurred anoda density of 80 plants per 12 meters. Full-season competition by 40 and 80 spurred anoda plants per 12 meters reduced cotton yield 40 and 73 percent, respectively. The yield-reduction trends were similar to the trends indicated by the reductions in cotton LAI and growth rate. At Stoneville, full-season spurred anoda competition at densities greater than 8 plants per 12 meters of crop row resulted in significant yield reductions (fig. 16). Spurred anoda plants emerging 2 weeks after cotton emergence and competing until harvest caused yield reductions at 16 plants per 12 meters, while plants emerging 4 or 6 weeks after cotton emergence did not reduce yields at any density.

The growth and yield data indicate that spurred anoda is a very competitive weed in cotton. The competitiveness becomes apparent as spurred anoda obtains enough size or leaf area or both to intercept light and absorb soil water and nutrients at a rate equivalent to that of cotton. Spurred anoda and cotton grow at similar rates the first 4 to 6

Table 3.—Dry weight of spurred anoda plants after competing with cotton at five densities and three durations, Stoneville, Miss., 1973–74

Spurred anoda density (plants/12 m)	Dry weight at three competition periods[1] (g/plant): Emergence to harvest	Emergence delay after cotton emergence: 2 weeks	Emergence delay after cotton emergence: 4 weeks
4	284a	156cd	2e
8	261ab	180bc	11e
16	204abc	120cd	2e
32	182bc	132cd	2e
64	120cd	70de	7e

[1]Means not followed by a common letter differ significantly from one another at the 5-percent level by Duncan's multiple-range test.

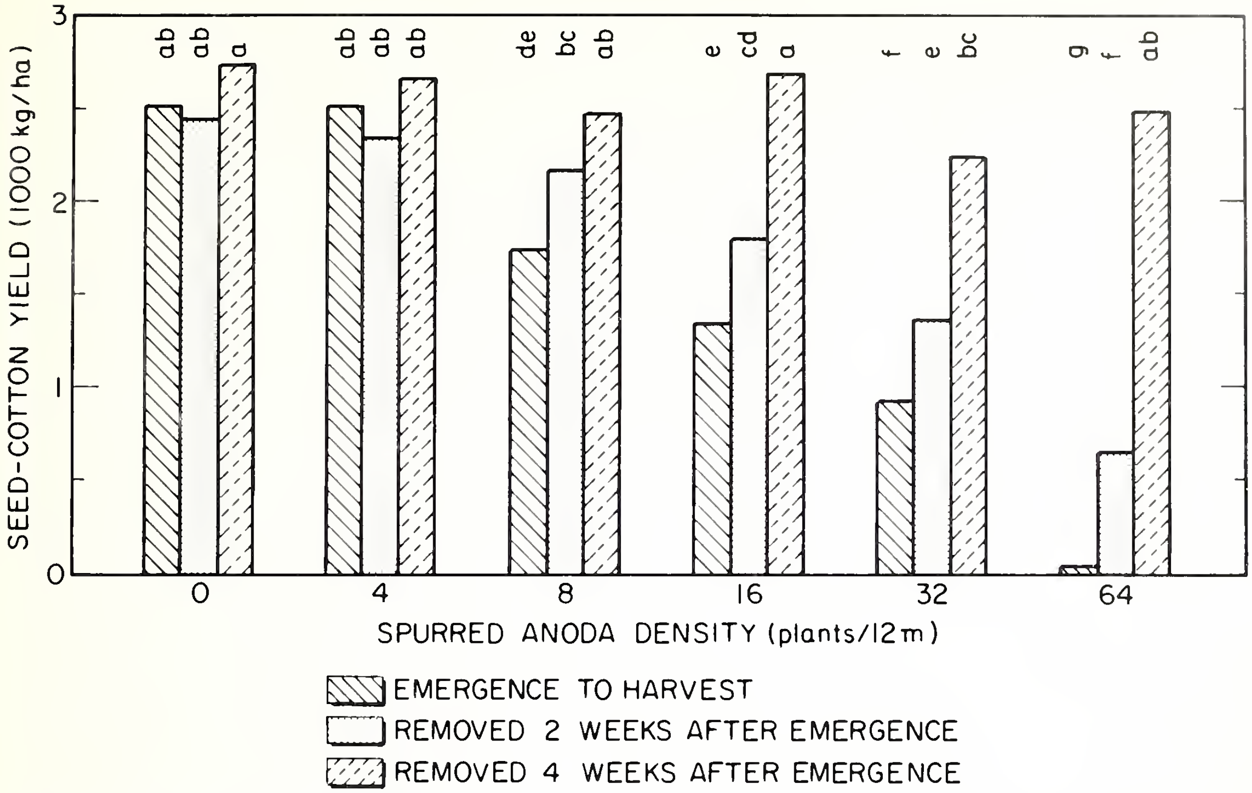

FIGURE 16.—Seed-cotton yields as influenced by spurred anoda competition at three durations and six densities, Stoneville, Miss., 1973–74. Data bars not followed by a common letter differ significantly from one another at the 5-percent level by Duncan's multiple-range test.

weeks after emergence. However, at 6 weeks, spurred anoda grows at a faster rate. In soybeans, spurred anoda did not reach an LAI or growth rate great enough to cause shading and increased competition for moisture and nutrients. Soybean yield was not significantly reduced by any spurred anoda density or duration of competition (fig. 17).

CONTROL IN COTTON

Herbicidal control of spurred anoda is difficult in cotton because the plants, being of the same botanical family, have similar growth habits and herbicide tolerances. Spurred anoda was first reported as a weed problem in West Texas by Smith and Cooley (1973) in 1970. The weed was not effectively controlled by any of the postemergence herbicides then being applied, and there was no evidence that new seedlings were controlled by any recommended cotton preemergence herbicide. In 1973, Baker and Ivy reported that no preemergence herbicide evaluated in their study gave satisfactory control of spurred anoda in cotton. In their 1974 study, norflurazon (refer to the appendix for trade and chemical names) gave the best preemergence control, and over 90 percent control of spurred anoda was obtained with two postdirected applications (postemergence ground sprays) of either MSMA plus methazole or MSMA plus dinoseb.

We screened herbicides at Stoneville, Miss., from 1972 through 1976 on pure stands of spurred anoda (Chandler 1975). Fluridone, an experimental cotton herbicide, was the only preplant-incorporated treatment that provided adequate control (table 4). Effective preemergence herbicides were fluridone, norflurazon, tetrafluron, and cyanazine. Effective postemergence herbicides were methazole, cyanazine, and methazole plus MSMA (table 5).

In production fields we evaluated preemergence cotton herbicides in 1973, 1974, 1976, and 1977 at Wilson and Keiser, Ark., and at Stoneville, Miss. (table 6). Norflurazon and fluridone were the most effective, followed by tetrafluron and perfluidone; methazole and fluometuron were ineffective. Lower control with norflurazon in 1974 was due to very dry conditions during the first 3 weeks after application,

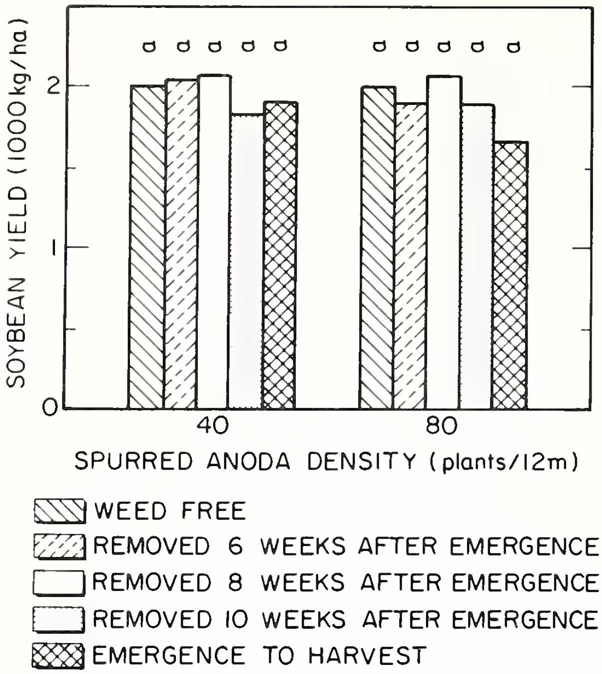

FIGURE 17.—Soybean yields as influenced by spurred anoda competition at five durations and two densities, Fayetteville, Ark., 1974. Data bars not followed by a common letter differ significantly from one another at the 5-percent level by Duncan's multiple-range test.

but even under these adverse conditions, it still provided 89 percent control. Jordan and Baker (1975) also reported that norflurazon applied at 1.0 to 20 pounds per acre preemergence gave excellent control.

In 1974, we took a systems approach to herbicidal control of spurred anoda in cotton at Keiser, Ark. (table 7). Norflurazon continued to be the most effective preemergence treatment (92 percent control). Fluometuron gave unacceptable preemergence control (13 percent). Methazole plus MSMA (96 percent) and tetrafluron plus MSMA (84 percent) were the most effective postdirected treatments. A combination of the more effective preemergence and postemergence treatments provided excellent full-season selective control of spurred anoda. Solano et al. (1976a) similarly reported that preemergence application of norflurazon in combination with either methazole, prometryn, or fluometuron postdirected and preemergence application of fluometuron plus methazole postdirected gave 94 to 100 percent full-season control. Jordan and Baker (1975) have also reported that postdirected applications of dinoseb (1.5 pounds per acre) plus MSMA (2.0 pounds per acre) applied at 3- to 4-inch and 6- to 8-inch cotton gave 95 percent control.

Under conditions of vigorous recurring infestations, no single preemergence or postemergence treatment will adequately suppress spurred anoda throughout the cotton-growing season. A combination of an effective preemergence treatment with at least one and possibly two applications of an effective postemergence treatment will be necessary. Crop rotation to soybeans, corn, or grain sorghum could be an effective control measure, as discussed in the following section.

Ohr et al. (1975) investigated the biological control of spurred anoda in cotton by a naturally occurring plant rust caused by two fungi tentatively identified as *Puccinia heterospora* and an *Alternaria* species. In fields heavily infested with the rust, surviving spurred anoda plants were not found. Comparison of healthy plants and spurred anoda infested with either or both fungi showed that the fungi caused reductions of 58 percent in height, 94 percent in plant dry weight, 100 percent in number of seed pods produced, and 100 percent in seeds per plant.

CONTROL IN SOYBEANS

The potential for control of spurred anoda is much greater in soybeans than in cotton because of the ability of soybeans to compete with spurred anoda. Soybean competitiveness along with the use of preemergence herbicides allows for much easier and earlier establishment of weed-crop height differentials that are necessary for effective postemergence herbicide applications.

In screening studies, oxadiazon, metribuzin, linuron, and cyanazine provided effective preemergence control of spurred anoda in soybeans (table 4). Bentazon was the only tested postemergence herbicide effective in soybeans (table 5).

Metribuzin was the most effective preemergence treatment in the test conducted at Keiser in 1974 (table 8), with 100 percent control and only slight soybean injury. Naptalam plus dinoseb applied at the soil-cracking stage gave much lower control (10 percent); however, the low control rating was due primarily to very few spurred anoda being present at the time of application. Preemergence application of alachlor was ineffective. Bentazon over the top or metribuzin postdirected and the combination treatment of bentazon over the top at the V2 stage of soybean growth (completely unrolled leaf at the

(*Continued on page 16.*)

Table 4.—Susceptibility of spurred anoda to preplant-incorporated and preemergence herbicides, Stoneville, Miss., 1972–76[1]

[In order of decreasing effectiveness, by herbicide type]

Herbicide	Rate[2] (lb/acre)	Spurred anoda control[3] (percent)
PREPLANT-INCORPORATED COTTON HERBICIDES		
Fluridone	0.30	100
Fluridone	.60	100
EPTC	4.00	67
Dinitramine	.50	37
Methazole	2.00	33
Profluralin	.75	17
Trifluralin	.75	5
PREEMERGENCE COTTON HERBICIDES		
Fluridone	0.60	100
Norflurazon	3.00	95
Tetrafluron	2.00	95
Cyanazine	2.00	91
Norflurazon	2.00	91
Perfluidone	4.00	85
Tetrafluron	1.00	84
Norflurazon	1.50	83
Fluridone	.30	73
Perfluidone	2.00	70
Fluometuron	1.50	61
Methazole	2.00	30
Diuron	1.00	22

Herbicide	Rate[2] (lb/acre)	Spurred anoda control[3] (percent)
PREPLANT-INCORPORATED SOYBEAN HERBICIDES		
Dinitramine	0.50	37
Profluralin	.75	17
Trifluralin	.75	5
PREEMERGENCE SOYBEAN HERBICIDES		
Oxadiazon	1.00	100
Metribuzin	.75	99
Linuron	2.00	95
Cyanazine	2.00	91
Vernolate	4.00	71
Bifenox	2.00	61
Acifluorfen	1.00	10
Metolachlor	3.00	2
Alachlor	3.00	2
PREEMERGENCE CORN AND GRAIN SORGHUM HERBICIDES		
Cyanazine	2.00	91
Atrazine	2.00	98
Propazine	2.00	97
Propachlor	5.00	90
LSD (0.05), all treatments		17

[1]Soil type: Bosket sandy loam with 1.22 percent organic matter. Spurred anoda grown in pure stands. LSD = Least significant difference.

[2]To convert pounds per acre to kilograms per hectare, multiply rate by 1.12.

[3]Visual ratings taken 4 weeks after plant emergence.

Table 5.—Susceptibility of spurred anoda to postemergence herbicides, Stoneville, Miss., 1972–76[1]

[In order of decreasing effectiveness, by herbicide type]

Herbicide	Rate[2] (lb/acre)	Leaf stage	Spurred anoda control[3] (percent)
COTTON HERBICIDES			
Methazole	0.75	3	95
Cyanazine	.50	3	94
Methazole + MSMA	.75+1.65	3	92
Cyanazine	.50	5	80
Methazole	.75	5	73
Methazole + MSMA	.75+1.65	3	72
Fluometuron + MSMA	.75+1.65	5	13
SOYBEAN HERBICIDES			
Bentazon	1.00	3	98
Bentazon	1.00	5	73
LSD (0.05), all treatments			21

[1]Soil type: Bosket sandy loam with 1.22 percent organic matter. Spurred anoda grown in pure stands. LSD = Least significant difference.
[2]To convert pounds per acre to kilograms per hectare, multiply rate by 1.12.
[3]Visual rating taken 4 weeks after application.

Table 6.—Control of spurred anoda in cotton with preemergence herbicides at Wilson and Keiser, Ark., and Stoneville, Miss., 1973, 1974, 1976, and 1977

[In order of decreasing herbicide effectiveness]

Herbicide	Rate[1] (lb/acre)	Spurred anoda control 1 month after application (percent)			
		Wilson[2] (1973)	Keiser[2] (1974)	Stoneville[3]	
				1976	1977
Fluridone	[4]0.50	—	—	92	100
Fluridone	.50	—	—	100	100
Norflurazon	1.50	97	89	100	99
Fluometuron	2.00	67	22	79	72
Tetrafluron	2.00	93	68	—	—
Perfluidone	4.00	87	62	—	—
Methazole	2.00	61	—	—	—
LSD (0.05)[5]		19	20	8	9

[1]To convert pounds per acre to kilograms per hectare, multiply rate by 1.12.
[2]Soil type: Sharkey clay loam with 2 percent organic matter.
[3]Soil type: Bosket sandy loam with 1.22 percent organic matter.
[4]Preplant-incorporated.
[5]LSD = Least significant difference.

Table 7.—Control of spurred anoda in cotton with combined preemergence and postemergence applications of herbicides, Keiser, Ark., 1974[1]

[Percent control]

Postemergence treatment[2]	Preemergence treatment[2]				
	No-herbicide check	Herbicide			
		Norflurazon, 1.50 lb/acre	Perfluidone, 4.00 lb/acre	Tetrafluoron, 2.00 lb/acre	Fluometuron, 2.00 lb/acre
No-herbicide check	0	92	72	74	13
Herbicide (lb/acre):[3]					
Fluometuron (1.00) + MSMA (1.60)	34	84	90	84	55
Methazole (0.75) + MSMA (1.60)	96	95	92	94	95
Prometryn (0.75) + MSMA (1.50)	46	93	96	93	62
Tetrafluoron (0.50) + MSMA (2.00)	84	90	95	93	92

[1]Soil type: Sharkey clay loam with 2 percent organic matter. Least significant difference, all treatments, at 5-percent level = 5.

[2]To convert pounds per acre to kilograms per hectare, multiply rate by 1.12.

[3]Herbicides postdirected at 3- to 4-inch stage of cotton growth; treatment repeated at 6- to 8-inch stage. Wetting agent present in all postemergence herbicide treatments.

Table 8.—Control of spurred anoda in soybeans with combined preemergence and postemergence applications of herbicides, Keiser, Ark., 1974[1]

[Percent control]

Postemergence treatment[2]	Preemergence treatment[2]			
	No-herbicide check	Herbicide		
		Metribuzin, 1.00 lb/acre	Naptalam, 3.00 lb/acre, + dinoseb, 1.40 lb/acre[3]	Alachlor, 3.00 lb/acre
No-herbicide check	0	100	10	20
Herbicide applied at V2 stage; repeated at V4 stage (lb/acre):[4]				
Bentazon (1.00)	100	100	100	100
Dinoseb (1.00 at V2 and 1.50 at V4)	45	100	90	90
Chloroxuron (1.00)	85	100	55	80
Herbicide applied at V4 stage (lb/acre):[4]				
Metribuzin (0.25)	100	100	100	100
Linuron (0.50)	75	100	72	100
Bifenox (1.00)	100	100	90	100
Bentazon (1.00 at V2) and metribuzin (0.20) + 2,4-DB (0.20) at V4	100	100	100	100

[1]Soil type: Sharkey clay loam with 2 percent organic matter. Least significant difference, all treatments, at 5-percent level = 5.

[2]To convert pounds per acre to kilograms per hectare, multiply rate by 1.12.

[3]Applied at the soil-cracking stage of soybean development.

[4]Herbicides applied over the top at V2 stage of soybean growth; postdirected at V4 stage. V2 = Completely unrolled leaf at the 1st node above the unifoliolate leaves. V4 = 3 trifoliolate leaves. Wetting agents used in V4 dinoseb, metribuzin, linuron, bifenox, and metribuzin + 2,4-DB treatments, the last of which was applied as a tank mix. Nonphytotoxic oil at 1:40 used in V4 chloroxuron treatment.

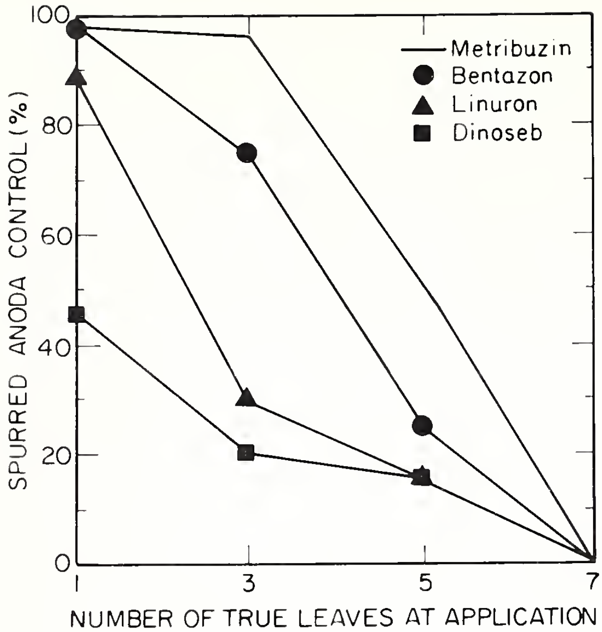

FIGURE 18.—Herbicide effectiveness at four stages of spurred anoda growth, Fayetteville, Ark., 1974.

first node above the unifoliolate leaves) followed by metribuzin plus 2,4-DB as a tank mix postdirected at the V4 state (three trifoliolate leaves) gave 100 percent control. Postemergence control was higher than expected and resulted from dry weather, which reduced the rate of spurred anoda growth and also its emergence.

In a greenhouse study conducted at Fayetteville, Ark., we evaluated proper timing of postemergence herbicide applications necessary for effective control of spurred anoda. As spurred anoda grew, it became increasingly tolerant to postemergence herbicides, until, at the seven-leaf stage, none of the herbicides tested was effective (fig. 18). Metribuzin applied over the top was the most effective, maintaining 98 and 96 percent control at the one- and three-leaf stages, respectively. At the five-leaf stage, effectiveness decreased to 45 percent control. Bentazon was equally as effective as metribuzin at the one-leaf stage, but effectiveness decreased to 75 percent at the three-leaf stage and 25 percent at the five-leaf stage. Wuerzer et al. (1972) and Mathis and Oliver (1975) have reported similar spurred anoda susceptibility to bentazon. These results illustrate the importance of applying postemergence herbicides early to control spurred anoda.

Crop rotation from cotton to soybeans would be a very effective means of controlling spurred anoda

Table 9.—Estimated reduction in seed-cotton yield from spurred anoda competition of various plant densities and durations[1]

[Percent]

Spurred anoda density (plants/12 m)	Weeks free of spurred anoda after initial cotton emergence					
	0	1	2	3	4	6
4	12	12	10	7	3	0
6	22	21	18	14	8	0
8	29	27	23	18	11	0
10	34	31	27	20	12	0
12	38	35	29	22	14	0
16	44	39	33	25	16	0
20	48	42	36	27	16	0
24	52	46	38	28	17	0
32	56	49	40	30	18	0
40	60	52	42	31	18	0
56	64	55	44	32	18	0
80	69	58	46	32	18	0

[1]Utilizing data from figures 15 and 16, a mathematical equation was developed to estimate yield reduction.

since soybeans are stronger competitors, and effective preemergence and postemergence herbicides for spurred anoda control in soybeans are available. In our herbicide-screening studies on pure stands of spurred anoda, atrazine, propachlor, and propazine applied preemergence provided excellent control (table 4). Since these herbicides are cleared for use in grain sorghum and corn, a rotation sequence including these crops could be very useful. Smith and Cooley (1973) suggested a possible control program in West Texas of rotating to grain sorghum in infested fields where propazine or atrazine would be used.

ECONOMIC IMPACT OF SPURRED ANODA IN COTTON

Previous sections of this publication have demonstrated that spurred anoda is a problem basically in cotton. Both reduction in cotton yield and cost of control must be considered in evaluating spurred anoda as an economically important weed (Chandler and Cooke 1977).

The estimated loss in seed-cotton yield from spurred anoda competition is shown in table 9. Spurred anoda has an adverse effect on cotton yield when it is present during early stages of cotton-plant development. Densities as low as 6 plants per 12 meters of row reduce yield 22 percent during full-season competition. As spurred anoda densities

Table 10.—Estimated cost of full-season weed control in solid cotton grown on sandy soil, Mississippi Delta practices, six-row equipment, 1976[1]

Operation	Cost (dollars per acre) Tractor Direct	Tractor Fixed	Equipment Direct	Equipment Fixed	Labor	Material	Total
Disk (21 ft); broadcast and incorporate 0.5 lb trifluralin per acre	0.51	0.60	0.52	0.96	0.41	3.47	6.47
Plant; apply 0.5 lb fluometuron per acre (20-inch band on 40-inch row spacing)	0	0	0	0	0	3.34	3.34
Cultivate	.60	.70	.19	.37	.48	0	2.34
Cultivate; postdirect 1.15 lb MSMA per acre (20-inch band on 40-inch row spacing)	.68	.80	.29	.56	.55	1.13	4.01
Cultivate; postdirect 0.44 lb fluometuron + 1.15 lb MSMA per acre (20-inch band on 40-inch row spacing)	.68	.80	.29	.56	.55	3.65	6.53
Hand hoe (2 hours per acre)	—	—	—	—	4.60	—	4.60
Cultivate; postdirect 1.15 lb of MSMA + 0.15 lb diuron per acre (20-inch band on 40-inch row spacing)	.51	.60	.22	.42	.41	1.56	3.72
Do	.51	.60	.22	.42	.41	1.56	3.72
Hand hoe (2 hours per acre)	—	—	—	—	4.60	—	4.60
Cultivate; postdirect 1.0 lb linuron per acre	.51	.60	.22	.42	.41	7.10	9.26
Total	4.00	4.70	1.95	3.71	12.42	21.81	48.59
Interest on operating capital							1.58
Total							50.17

[1]To convert dollars per acre to dollars per hectare, multiply cost by 2.471. To convert pounds per acre to kilograms per hectare, multiply rate by 1.12.

increase, the competitiveness from an individual spurred anoda plant is decreased because it competes with itself. Full-season competition from 80 spurred anoda per 12 meters of row reduces cotton yield 69 percent.

Estimates were made to determine the cost of controlling spurred anoda at a density of 60 plants per 12 meters of row. A standard weed-control system used in the Mississippi Delta includes trifluralin incorporated before planting, fluometuron applied preemergence, MSMA and fluometuron plus MSMA applied as early postdirected treatments, mechanical weed control, and some hand hoeing (table 10). The system costs $50 per acre (1976 prices) and would control 60 percent of the spurred anoda, leaving 24 plants per 12 meters of row. The substitution of norflurazon for fluometuron as the preemergence herbicide and methazole for fluometuron plus MSMA as a postdirected herbicide would reduce the infestation level 95 percent, leaving 1 plant per 12 meters of row. This herbicide substitution would cost an additional $5 per acre and would increase yield as much as 52 percent (table 9), or gross income $185 per acre (table 11). To approach total control of spurred anoda, an additional 5 hours of hoeing, or an expenditure of $11.50 per

Table 11.—Estimated loss of gross income from spurred anoda competition of various densities and durations in cotton[1]

[Dollars per acre]

Spurred anoda density (plants/12 m)	Weeks free of spurred anoda after initial cotton emergence 0	1	2	3	4	6
4	43	43	36	25	11	0
6	78	75	64	50	28	0
8	103	96	82	64	39	0
10	121	110	96	71	43	0
12	135	125	103	78	50	0
16	157	139	117	89	57	0
20	171	150	128	96	57	0
24	185	164	135	100	60	0
32	199	174	142	107	64	0
40	214	185	150	110	64	0
56	228	196	157	114	64	0
80	246	206	164	114	64	0

[1]Weed-free check yielded 500 lb/acre of lint at $0.60/lb and 930 lb/acre of seed at $0.06/lb, for a gross income of $356/acre. To convert dollars per acre to dollars per hectare, multiply cost by 2.471.

acre, would be required. The extra hoeing would not increase gross returns. Thus, intensive hoeing is not economically feasible.

Gross-income loss at several spurred anoda densities is presented in table 11. Comparing reductions in gross income from each spurred anoda infestation period gives an indication of the economic importance of early-season control. Spurred anoda densities as low as 4 plants per 12 meters of row are economically feasible to control within the first 3 weeks following cotton emergence. When spurred anoda is controlled for the first 6 weeks after cotton emergence, no economic advantage accrues to this year's crop by further control. However, seeds produced after 6 weeks may adversely affect next year's crop, and so further control efforts may be agronomically and economically desirable.

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APPENDIX.—COMMON, TRADE, AND CHEMICAL NAMES OF HERBICIDES

Common name	Trade name	Chemical name
Acifluorfen	Blazer	Sodium 5-[2-chloro-4-(trifluoromethyl)-phenoxy]-2-nitrobenzoate.
Alachlor	Lasso	2-Chloro-2′,6′-diethyl-*N*-(methoxymethyl)acetanilide.
Atrazine	AAtrex	2-Chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine.
Bentazon	Basagran	3-Isopropyl-1*H*-2,1,3-benzothiadiazin-(4)3*H*-one 2,2-dioxide.
Bifenox	Modown	Methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate.
Chloroxuron	Tenoran, Norex	3-[*p*-(*p*-Chlorophenoxy)phenyl]-1,1-dimethylurea.
Cyanazine	Bladex	2-[[4-Chloro-6-(ethylamino)-*s*-triazin-2-yl]amino]-2-methylpropionitrile.
Dinitramine	Cobex	N^4,N^4-Diethyl-α,α,α-trifluoro-3,5-dinitrotoluene-2,4-diamine.
Dinoseb	Premerge, Basanite.	2-*sec*-Butyl-4,6-dinitrophenol.
Diuron	Karmex	3-(3,4-Dichlorophenyl)-1,1-dimethylurea.
EPTC	Eptam	*S*-Ethyl dipropylthiocarbamate.
Fluridone	EL 171	1-Methyl-3-phenyl-5-[3-(trifluoremethyl)phenyl]-4(1*H*)- pyridinone.
Fluometuron	Cotoran, Lanex	1,1-Dimethyl-3-(α,α,α-trifluoro-*m*-tolyl)urea.
Glyphosate	Roundup	*N*-(Phosphonomethyl)glycine.
Linuron	Lorox	3-(3,4-Dichlorophenyl)-1-methoxy-1-methylurea.
Methazole	Probe	2-(3,4-Dichlorophenyl)-4-methyl-1,2,4-oxadiazolidine-3,5-dione.
Metolachlor	Dual	2-Chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide.
Metribuzin	Sencor, Lexone	4-Amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one.
MSMA	Daconate, Ansar 529.	Monosodium methanearsonate.
Naptalam + dinoseb	Dyanap, Ancrack, Klean Krop.	*N*-1-Naphthylphthalamic acid.[1]
Norflurazon	Zorial	4-Chloro-5-(methylamino)-2-(α,α,α-trifluoro-*m*-tolyl)-3(2*H*)-pyridazinone.
Oxadiazon	Ronstar	2-*tert*-Butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-Δ^2-1,3,4- oxadiazolin-5-one.
Perfluidone	Destun	1,1,1-Trifluoro-*N*-[2-methyl-4- (phenylsulfonyl) phenyl]methanesulfonamide.
Profluralin	Tolban	*N*-(Cyclopropylmethyl)-α,α,α-trifluoro-2,6-dinitro-*N*-propyl- *p*-toluidine.
Prometryn	Caparol	2,4-bis(Isopropylamino)-6-(methylthio)-*s*-triazine.
Propachlor	Ramrod, Bexton	2-Chloro-*N*-isopropylacetanilide.
Propazine	Milogard	2-Chloro-4,6-bis(isopropylamino)-*s*-triazine.
Tetrafluron	HOE 2991	*N*,*N*-Dimethyl-*N*′-[3-(1,1,2,2-tetrafluoroethoxy)phenyl]urea.
Trifluralin	Treflan	α,α,α-Trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine.
2,4-DB	Butoxone, Butyrac.	4-(2,4-Dichlorophenoxy)butyric acid.
Vernolate	Vernam	*S*-Propyl dipropylthiocarbamate.

[1]Chemical name for naptalam. See "dinoseb" for its chemical name.

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